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The effectiveness of a head-heart-hands model for natural and environmental science learning in urban schools

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ABSTRACT

We describe an environmental and natural science program called Nurture thru Nature (NtN) that seeks to improve mathematics and science performance of students in disadvantaged communities, and to increase student interest in Science, Technology, Engineering and Mathematics (STEM) careers. The program draws conceptual guidance from the Head-Heart-Hands model that informs the current educational movement to foster environmental understanding and sustainability. Employing an experimental design and data from seven cohorts of students, we find some promising, albeit preliminary, indications that the program can increase students' science knowledge and grades in mathematics, science and language arts. We discuss the special adaptations that environmental and sustainability education programs need to incorporate if they are to be successful in today's resource depleted urban schools.

1. Introduction

The need for individuals who possess skills in science, technology, engineering and mathematics (STEM) has never been greater in our country. Yet as recent reports from both business and government sectors indicate, millions of these STEM jobs remain unfilled in large measure because of a skills shortage in America's labor market (U.S. Congress Joint Economic Committee Report, 2012; U.S. Department of Commerce, 2011). In a 2015 report to Congress, the Committee on Equal Opportunities in Science and Engineering (2015) identified poor elementary and high school education as one of the major reasons that STEM careers are ignored, dismissed or abandoned. This dynamic is especially prominent among minority students in our inner cities.

Since the early 1990s the achievement gap between white students on the one hand, and black and Hispanic students on the other, has remained disturbingly large (National Center for Education Statistics, 2013). Much of the available research indicates that this gap widens over time, is accelerated over the summer break, and is not limited to cognitive skills, but affects non-cognitive skills as well (Heckman, 2013; Fryer and Levitt, 2004). A consensus has also emerged that interventions to improve academic performance are best targeted at younger (elementary) school students; these interventions do not face the equity-efficiency tradeoff characterized by programs for adolescents (Heckman, 2013; Heckman and Masterov, 2008).

In this paper we report results from an evaluation of the Nurture thru Nature (NtN) program in seven elementary schools serving disadvantaged black and Hispanic students in Central New Jersey, USA. NtN is a natural/environmental science initiative that attempts to improve the basic science, mathematics and language arts performance of disadvantaged elementary and middle school students and use this improvement as a platform for stimulating interest in STEM disciplines and careers. The program is inspired by the "Head, Heart and Hands" environmental educational model articulated by Singleton (2015) which has its roots in the active learning philosophy of John Dewey (1976,1990. The NtN program is designed as a classical experiment with random assignment to treatment and control groups and operates as an after-school as well as a summer enrichment program. NtN makes active use of the aesthetics readily found in nature to excite student imagination and engender a deeper scientific understanding of the interconnections among persons, community and the environment.

2. Background literature

There is a growing consensus among educators in the sustainability movement that "hands on" environmental and natural science teaching opens pathways for young students to STEM and green careers (Aikens, McKenzie, & Vaughter, 2016; U.S. Department of Education, N.D.). Inasmuch as a good deal of the literature has been discussed elsewhere (Camasso & Jagannathan, 2017), we provide a brief synopsis here.

Lieberman and Hoody (1998) have evaluated the influence of a

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curriculum called Environment as Integrating Context in 40 elementary, middle and high schools from across the United States. The researchers report higher Grade Point Average (GPA), language arts, mathematics, and science grades for elementary and middle school students. Garden and outdoor-based, nature curriculum has also been reported to increase student achievement in several additional studies (Gaylie, 2011; Hirschi, 2015; Royal Horticulture Society, 2010). Critics of this research (Blair, 2009; Williams & Dixon, 2013) note that many of the findings of this research are compromised by weak research designs, short follow-up periods, lack of a clear counterfactual and absence of controls for teacher effects.

After-school programs designed to improve the reading, mathematics and science performance of disadvantaged students have become an increasingly popular approach to bridging the achievement gap. Despite widespread praise, the effectiveness of these programs remains unsettled. Hollister (2003), Fashola (1998), Lauer et al. (2006), among others, assert that the evaluation literature on after-school programs is plagued by poor conceptualization, weak design, and publication outside the perimeter of peer reviewed journals.

In their sweeping review of the 150 evaluations of after-school programs listed by the Harvard Family Research Project that includes such highly publicized endeavors as the 21st Century Community Learning Centers, Big Brothers, Big Sisters, and the Quantum Opportunities program, Levine and Zimmerman (2010) report a preponderance of disappointing results. In the rare instances where math or reading effects are found to be significant, most effects disappeared after a one year follow-up.

Efforts have also increased to combat the problem of “summer fallback,” i.e., abrupt increases in the size of the achievement gap that occur after summer recess (Alexander, Entwisle, & Olsen, 2007; Hanushek & Rivkin, 2009). While results from evaluations of summer programs like Building Educational Leaders for Life have been promising, mathematics effects, especially, have been exceedingly small and never statistically significant (Somers, Welbeck, Grossman, & Gooden, 2015). Evaluators here have attributed the dearth of positive effects to the problem of “underpowered treatment,” i.e., low dosages of program treatment due to recruitment issues, weak research designs, short treatment periods and low student attendance (McCombs et al., 2011; Somers et al., 2015; Robinson-O’Brien et al., 2009). The problem of underpowered treatment would also appear to be a factor in evaluations of enhanced science/math curriculum and after-school programs as well.

3. The NtN intervention

3.1. Conceptual framework

Nurture thru Nature (NtN) attempts to overcome the limitations of some environmental science interventions targeted at disadvantaged youth through a program of clear conceptualization of purpose, sufficient treatment dosage, and strong evaluation design. NtN draws heavily from the seminal work of John Dewey, recognizing that children are never passive recipients of education but rather are actively engaged agents in their own life’s dramas. There is an additional recognition that young students, regardless of background or family resources, have a wellspring of uninvested human capital that can be directed into communication, construction, inquiry, and abstract thinking if teaching takes a personal approach, understanding how student interests and habits derive from their homes and neighborhoods (Dewey, 1976:p.30; Dewey, 1990:p.463). In many ways, NtN is quite congruous with the “Head, Heart and Hands” model for transformative learning articulated by Singleton (2015).

As described by Singleton (2015), the “Head, Heart and Hands” model for transformative learning, as inspired by Dewey, is designed to promote student learning through the simultaneous involvement of intellect, emotion and body. In her own words:

> “The model shows the holistic nature of transformative experience and relates the cognitive domain (head) to critical reflection, the affective domain (heart) to relational knowing and the psychomotor domain (hands) to engagement. This model not only represents the multi-dimensional nature of transformative processes, it also includes the importance of learning context. The context of place provides a framework of authentic experience for deeper reflection, sense of belonging and body/sensory stimulation that acts as a catalyst for deep engagement.”

What the Head, Heart and Hands model fails to do is to fully incorporate the reality of a resource depleted school environment into its conceptualization of learning context. In the authors’ experiences working with inner-city schools, we find the need to approach transformative learning from an underlying Maslowian template. Rather than apply the “Head, Heart and Hands” model as a non-recursive intervention with focus more-or-less evenly spread across cognitive, emotional and psychomotor domains, the exigencies and realities of the under-resourced urban school compel a hegemonic emphasis on cognitive learning. Because of the political and economic necessities described below, NtN can most accurately be described as a HEAD, Heart and Hands approach to environmental and sustainability education.

3.1.1. Core program components

The NtN program, initiated in 2010, is a partnership of Rutgers University faculty and students, the New Brunswick School District, and Johnson & Johnson. NtN was designed after a careful review of extant research on nature-based and environmental education. This literature pointed to a set of program inputs and activities that could be conceptually linked to improved academic performance for students. The program structure and operations of NtN were specifically designed to overcome the problem of “underpowered treatment” and the low dosage exposure it presaged. The structure intertwines 11 key components, of which 5 are of central importance, viz., a natural science curriculum aligned with the curriculum taught by public school science and math teachers; after-school and summer components that continued and reinforced school curriculum; math, language arts and science tutoring; the use of garden/naturescape assets that extended classroom teaching and provided opportunity of more in- depth and supplementary science learning, and a commitment to keep parents aware and involved in their child’s math and science education. These inputs, activities and expected outcomes are shown in Fig. 1 in the form of a logic model. The logic model also calls for the assessment of program impact on longer term outcomes in addition to the short and medium term outcomes that we focus on in this paper.

During the academic year, project-based learning and hands-on experiments support an NtN natural science and math curriculum that is aligned with the curriculum taught in the New Brunswick public schools. The academic year NtN curriculum is delivered after school for 3 h a day, 2-days a week. During the summer months of July and August, NtN continues the natural science curriculum enriched with more hands-on exercises for 7.5 h a day, 3 days a week. Fig. 2 presents some examples of the science topics receiving emphasis in grades 4 through 8. Classroom teaching on these topics are augmented with direct experiences in each grade.

Although NtN is focused on environmental and natural science education, time is reserved in each session to help students achieve advanced proficiency in both language arts and mathematics. Students receive reading assignments and problem sets with a natural science content, that are graded and discussed with students, individually or in small groups. Periodic assessments at the end of each science topic module are also conducted by NtN staff.

NtN summer and after-school instruction makes heavy use of the school naturescape/garden, a resource that offers a place for observation and identification, quiet reflection, hypothesis testing, and problem solving. The basic architecture of an NtN naturescape appears in Fig. 3

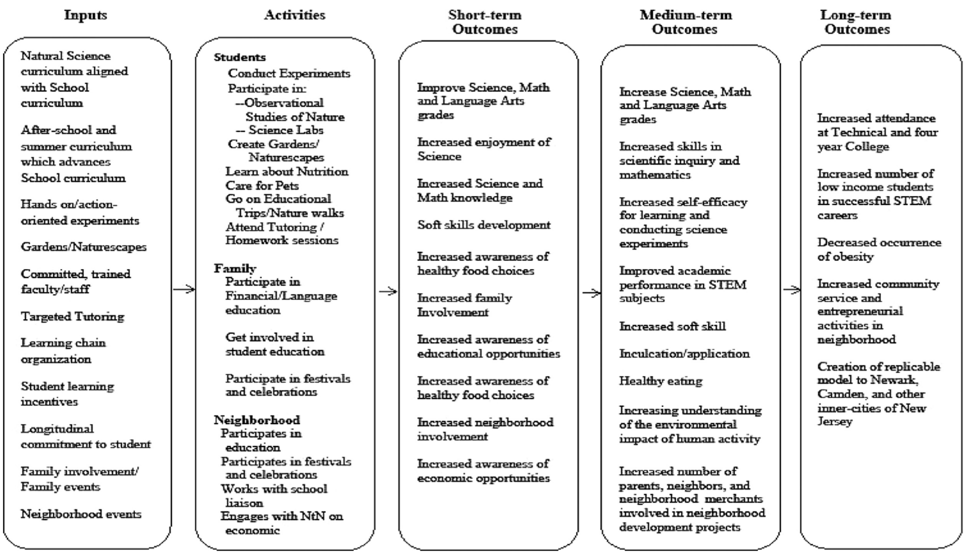

Fig. 1. Nurture thru Nature (NtN) Logic Model.

Grade Level	School Curriculum Focus	NtN Instruction	
		After School Program	Summer Program
Fourth Grade	Basic Astronomy, The Human Body, Rocks and Minerals	Rocks and Minerals, The Human Body	Basic Astronomy, Birds, Insects, Reptiles and Amphibians
Fifth Grade	Mixtures and Solutions, Elements and Atoms, Principles of Anatomy	Principles of Anatomy, Mixtures and Solutions	Fish, Pond Life, Basic Horticulture, Flowers
Sixth Grade	Forces and Motion, Electricity, and Basic Physics, Heat Transfer, The Human Brain	The Human Brain, Newton's Laws, The Scientific Method, Experimentation	Naturalistic Methods, Evolution and Ecologic niches, Photosynthesis
Seventh Grade	Acids and Bases, Mitosis and Meiosis, Osmosis and Diffusion, Basic Cell Biology	Cell Biology, Lab Reports, Principles of Micro-Biology, Eukaryotic and Prokaryotic Cells	Microscopic Pond Life, Healthy Foods and Nutrition, Gardening Techniques / Naturescape Development
Eighth Grade	Processes of Science, Forces and Motion, Energy Transformations, Light, Heat, Solar Energy and Weather, Rocks and the Rock Cycle,	Atoms and Elements, Evolution, The Processes of Science, Substances, Molecules	Tree Identification and Uses, Solar Energy and Weather

Fig. 2. NtN augmentation and extension of the Public School Science Curriculum – Grades Four through Eight.

with the principal components comprising an arched entranceway, a water feature (typically a pond with waterfall), butterfly and caterpillar gardens, an organic vegetable garden, and a composting station. In addition to serving as an oasis for nature in the schoolyard and a center for scientific inquiry, NtN naturescapes provide a venue for bringing families and neighbors together. They also provide students with the setting to study insects, flowers, trees, and birds in situ. Learning here ranges from classification and species identification to the understanding of complex processes like metamorphosis, pollination, parasitism, and niche changes. Water features extend this learning to fish, amphibians, aquatic plants, and pond microorganisms. The organic garden opens up instruction in the areas of fruit and vegetable cultivation, basic horticulture, plant pests, hybridization, and nutritional value.

NtN instructors include faculty and students (graduate and undergraduate level) from a wide variety of disciplines at Rutgers University in an attempt to operationalize Dewey's "University Elementary School" (Dewey, 1976: p.318). While an advanced degree in one of the 'hard' sciences is not a requirement for employment, a strong interest in nature/science, solid math skills, and a commitment to working with children and their families are essential prerequisites.

4. Evaluation design, data and methods

We employ a classical experimental design to measure NtN impact. Experiments have the useful quality of controlling for both measured and unmeasured factors that could, in addition to the NtN intervention, be responsible for changes in knowledge, attitudes, or behaviors. However, since this experiment is conducted in a natural setting, i.e., the school, it is possible that social interactions among students, home background factors, etc., could pose threats to the internal validity of this study. NtN and control students are assessed at the beginning of the academic year on a series of academic, attitudinal, or behavioral measures gleaned from school administrative databases, report cards, and student surveys. Data on these measures are again collected at the end of the school year. Inasmuch as random assignment helps to promote equivalency between groups at baseline, any differences in outcomes could be attributed to NtN barring threats to internal validity such as those mentioned above, as well as threats from differential attrition, interfering treatments or treatment contamination.

NtN began as a pilot program in one New Brunswick, New Jersey elementary school in May 2010, after 18 months of planning, partnership development and site preparation. Third grade students from this school (identified as Cohort 1 in this paper) were first stratified by classroom teacher and then by gender. Within each classroom (teacher), boys and girls were randomly assigned to the NtN group, a waiting list,[1] or a control group using a lottery. The stratification by classroom (teacher) was made to minimize any potential confounding effects due to teacher instruction style, subject knowledge and overall

[1] The waiting list was developed in anticipation of re-populating the treatment group in the event of student inability to join the program or student attrition from program.

Fig. 3. An NtN Naturescape.

Table 1
Descriptive Data on NtN and Control Students at Baseline – Cohorts 1–7.

Characteristic	Cohort 1		Cohort 2		Cohort 3		Cohort 4		Cohort 5		Cohort 6		Cohort 7	
	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.
Grade level	3	3	3	3	3	3	3	3	4	4	4	4	4	4
Female	55.6	38.5	50.0	56.1	57.1	45.2	35.7	47.9	40.0	38.3	66.7	64.9	52.6	44.4
Race/Ethnicity:														
Hispanic	77.8	71.8	75.0	79.0	92.9	85.7	100.0	95.1	93.3	85.2	55.6	63.9	68.4	50.0
Black	16.7	25.6	25.0	21.1	7.1	13.1	0.0	3.6	6.7	11.1	44.4	36.1	15.8	27.8
Free or reduced lunch	100.0	97.4	95.0	96.4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Speak English at home	27.8	28.2	45.0	32.7	16.7	19.3	7.1	11.0	14.3	20.0	66.7	57.1	68.4	50.0
IEP	6.6	4.3	6.7	6.8	30.8	25.7	14.3	15.6	6.7	23.5	38.9	32.4	31.6	22.2
Average Grade in:														
Math	80.1	79.5	82.2	79.9	78.7	80.0	80.8	81.2	81.3	79.2	72.0	75.7	77.2	76.7
Language Arts	79.5	76.9	77.9	77.4	77.4	77.3	78.6	78.4	84.6	80.8	76.4	76.7	78.4	78.8
Science	81.4	79.3	82.8	82.6	80.9	81.8	78.0	77.6	88.4	85.0	82.5	82.2	81.9	82.6
Average days absent	7.5	9.7	3.6	5.0	0.9	1.2	3.6	4.2	6.7	6.5	6.7	7.1	5.1	6.6
Average days tardy	n/a	n/a	1.2	1.9	5.6	2.4	0.9	1.4	1.3	1.6	5.4	7.8	3.5	3.6
Number of Students	18	39	20	57	14	84	14	140	15	81	18	37	19	18

quality of teaching. The process resulted in a total of 18 students comprising the NtN group, and 39 students populating the control group. Parents of the selected NtN students were asked by the school principal and the NtN directors to sign a consent form memorializing their permission to allow their children to participate in the set of learning opportunities and activities identified as NtN. This first cohort has remained with the NtN program for seven years (2010–2017), for whom academic data are available for six post-years.

In subsequent years, six additional cohorts of students were enrolled in the program from five different elementary schools in New Brunswick using the same random assignment procedures outlined above. Three of these cohorts (Cohorts 2, 3, and 4) began the NtN program in 2012 and had 4 years of NtN program experience; three cohorts (Cohorts 5, 6 and 7) joined NtN in 2014 and had 3 years of the NtN experience. Cohort 3, which began with 14 students had 9 students move to another school district or out of the country after the first year. Because the cohort did not yield sufficient data for any meaningful analysis, it was excluded from experimental/control group analyses.

Table 1 presents the profiles of the NtN and Control group students in all seven cohorts at baseline. We show evidence that random assignment appears to be successful in creating equivalency between NtN and control students at baseline on many of the measured characteristics, viz., gender, race/ethnicity, poverty (school lunch program), language spoken at home, average days of absence and tardiness, and average grade in mathematics, language arts, and science. Although there appear to be big differences in gender proportions (4 of 7 cohorts) and the percentage of homes where English is spoken primarily (3 of 7 cohorts), these differences are not statistically significant.

We follow the stylized analytic strategy for experimental data, testing for equality of means[2] and variances and reporting statistical significance. Alpha levels were set a 0.1 to acknowledge the small sample sizes. We focus on a comparison of significant post-period outcomes between NtN and control group students. It should be noted that the group comparisons were made independently for each year of the treatment and this approach to analysis could be seen as a limitation if the NtN impact varies over time. While the analysis of pooled, yearly data would allow the modeling of time and increase the experiment's power, pooling provides an estimate of treatment impact that obscures the grade-specific effects essential to gain a more thorough understanding of this demonstration program's dynamics. We present both descriptive, unadjusted results as well as regression-adjusted results,

[2] We use *t*-tests for testing equality of means while assuming unequal variances between groups and Welch's degrees of freedom adjustment given the differences in sample sizes.

Table 2
Cohort 1 – Six Year NtN Impacts – Descriptive Results.

Outcome	Post 1 (2010–11)		Post 2 (2011–12)		Post 3 (2012–13)		Post 4 (2013–14)		Post 5 (2014–15)		Post 5 (2015–16)	
	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.	NtN	Con.
School grade in:												
Math	83.2	81.6	82.6	81.0	72.9	70.8	74.5	72.6	74.3	72.5	75.1	73.1
Language Arts	82.5*	79.5	81.9	78.8	78.9	76.7	78.8**	74.9	79.5	77.4	75.6**	69.9
Science	83.6	82.8	83.2	82.1	81.3**	74.8	77.6	75.1	81.5*	75.7	74.5	73.5
Science Knowledge Assessment (% Correct Response)	50.7	47.1	50.0**	40.8	36.3	32.5	–	–	44.4	43.5	54.4**	45.2
School Absences (Days)	4.8*	7.5	3.5**	6.0	6.0*	9.0	7.9	7.7	3.5**	12.7	5.4*	9.1
Tardiness (Days)	1.4*	4.6	1.6	3.0	6.8	9.1	11.1	9.1	5.3	6.5	6.0	8.0
[a]n	17	33	15	30	16	24	14	35	11	20	11	22

[a] Number of observations may vary for academic vs. survey data - number of observations from survey data depends on student presence in school on day of survey administration.
* $p < 0.1$.
** $p < 0.05$.

where the latter control for any remaining differences in race/ethnicity, gender, and language spoken at home. Given the continuous nature of the outcomes used here, we employ ordinary least squares regression.

4.1. Data and data sources

Our impact measures include students' end-of-year school grades in mathematics, language arts and science, number of absent and tardy days, and scores from a science knowledge assessment instrument that also contained questions about student interest in STEM. All grades, absences and tardiness measures were gleaned from the school district's administrative database. At the end of each school year, a science knowledge assessment is completed by both the NtN and control group students. The assessment instrument was designed by NtN faculty in collaboration with New Brunswick public school science teachers, and gauges students' knowledge in various grade-specific science topics learned through the school year. The assessment contains on average about 45 items with a small subset of items that are repeated each year, and is administered at the school by school officials. The instrument also queries students about whether the school (or NtN program for program participants) has increased an interest in STEM or STEM related disciplines – science, mathematics, technology, and nature/environment. Interest was measured on a scale of 0–10 with 0 indicating 'not at all interested' and 10 indicating 'very much interested.' The STEM interest question was added to the assessment in 2016.

5. Results

In Table 2, we present descriptive, unadjusted NtN yearly impacts for six years, for the group with the longest NtN exposure, Cohort 1. Table 3 presents a side-by-side comparison of these results with regression-adjusted estimates. From both Tables, we see that NtN students achieve higher grades in mathematics, language arts, and science in all six years of the demonstration, scoring anywhere from 1.6 to 3.4 points higher than their control counterparts in mathematics, 2.1–5.8 points higher in language arts, and 0.8–6.5 points higher in science. The pattern holds true also of science knowledge assessment scores, with NtN students scoring anywhere from 1.0 to 9.2 points higher than control students.

While the differences between NtN and control students in mathematics increase consistently each year in the expected direction, they are not significant for any of the years. Language arts gains for NtN students are statistically significant in Post Years 1, 2, 4, and 6. NtN students also out-perform controls in science and science knowledge in all study years with the differences in school science grade reaching statistical significance in Post Years 3 and 5, and science knowledge becoming statistically significant in Post Years 2[3] and 6.

Table 2 also shows that NtN students had consistently lower absences and tardiness on average compared to control group students. In 5 of the 6 years (Post Years 1, 2, 3, 5, and 6) the difference in the average number of school absences, ranged anywhere from 2.5 to 9.2 fewer days, and is statistically significant. Differences in tardiness, however, are only significant in the first post year.

Table 3, which compares unadjusted and regression-adjusted impacts for Cohort 1 confirms results presented in Table 2 in terms of impact magnitude, direction of impact, and statistical significance. Regression-adjusted impacts are virtually the same as the unadjusted impacts in every instance where the NtN-control differences are statistically significant, indicating once again, the integrity of randomization.

Tables 4 and 5 present unadjusted and adjusted NtN impacts for Cohort 2, for whom four years of post-program data are available. Both Tables show that NtN students had significantly higher mathematics school grades relative to control students in each of the four post years, with the impact ranging from 4.3 to 6.1 points. While language arts grades did not differ significantly in any of the post years, NtN students did significantly better than their control counterparts in science in Post Years 1 and 4, scoring on average from 2.8 to 7.5 points higher. NtN students also had a significantly higher percentage of correct answers in science knowledge assessment (the difference ranging from 11.3 to 16.7 points) in Post Years 1, 2, and 3. Except for the first post year, there were no differences on average in the number of days absent or tardy between the two groups. A comparison of unadjusted and adjusted differences (Table 5) reveals that while the two impact estimates are congruent with respect to statistical significance, the regression adjusted estimates tend to be slightly lower.

In Tables 6 and 7, we present impact estimates for Cohort 4, with three years of post- program data. Here, we see that NtN students scored on average between 2.8 to 3.6 point higher in mathematics compared to control group students, a statistically significant difference in Post Years 1 and 2. While there is no program impact to report on language arts grades, NtN students exhibited substantial gains in school science grade and their overall science knowledge relative to control students. The difference of 4.8 points in science grades between the groups is statistically significant in Post Year 1; and the considerable

[3] Science assessment was not completed nor was the full complement of NtN services delivered to Cohort 1 during the School Year 2013–14 because of the original intent that NtN would be a 3-year program (grades 4, 5, and 6). Subsequently, with additional funding, the program curriculum was developed and extended to cover grades 7–12. During 2013–14, Cohort 1 met once a week after school with NtN staff for any homework help or tutoring, but participated fully as teacher assistants during the summer program.

Table 3
Comparison of Descriptive (unadjusted) and Regression-Adjusted[a] NtN Impacts – Cohort 1.

Outcome Measure	Post 1 (2010–11) Difference (NtN – Cont.)		Post 2 (2011–12) Difference (NtN – Cont.)		Post 3 (2012–13) Difference (NtN – Cont.)		Post 4 (2013–14) Difference (NtN – Cont.)		Post 5 (2014–15) Difference (NtN – Cont.)		Post 6 (2015–16) Difference (NtN – Cont.)	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Average grade in:												
Math	+1.63	+2.71	+1.6	+3.4	+2.1	+2.5	+1.9	+2.9	+1.8	+2.2	+2.0	+2.5
Language Arts	+3.0	+3.3[*]	+3.1[*]	+3.8[*]	+2.2	+2.2	+4.0[**]	+3.9[*]	+2.1	+2.4	+5.8[**]	+5.8[*]
Science	+0.8	+1.38	+1.1	+2.0	+6.5[**]	+6.5[**]	+2.6	+2.9	+5.7[*]	+5.9[*]	+1.0	+2.3
Science Knowledge	+3.6	+2.7	+9.2[**]	+10.3[**]	+3.8	+3.7	–	–	+1.0	−1.0	+9.2[**]	+9.2[**]
Absences	−2.7[*]	−2.9[*]	−2.5[**]	−3.1[**]	−3.0[*]	−3.5[*]	+0.1	−0.3	−9.2[**]	−9.8[**]	−3.7[*]	−4.0[*]
Tardiness	−3.4[*]	−3.7[*]	−1.4	−1.3	−2.4	−2.6	−1.9	+1.4	−1.3	−1.7	−2.0	−2.8

[a] Regression results adjust for gender, race/ethnicity and language spoken at home.
* $p < 0.1$.
** $p < 0.05$.

Table 4
Cohort 2 – Four Year NtN Impacts – Descriptive Results.

Outcome	Post 1 (2012–13)		Post 2 (2013–14)		Post 3 (2014–15)		Post 4 (2015–16)	
	NtN	Control	NtN	Control	NtN	Control	NtN	Control
School grade in:								
Math	81.4[**]	77.1	87.1[**]	82.5	82.1[**]	76.5	79.4[*]	73.3
Language Arts	82.3	80.0	82.3	81.2	77.8	76.4	78.0	75.4
Science	83.9[**]	81.1	86.9	85.0	76.0[b]	77.6	85.8[**]	78.3
Science Knowledge Assessment (% Correct Response)	54.0[**]	42.3	65.5[**]	50.1	64.6[**]	47.9	68.3	62.9[c]
School Absences (Days)	3.7[**]	5.5	3.7	4.7	5.7	6.0	7.1	6.4
Tardiness (Days)	2.9	3.0	4.4	2.8	6.7	5.9	4.8	7.0
[a]n	19	53	15	56	15	51	11	44

[a] Number of observations may vary for academic vs. survey data - number of observations from survey data depends on student presence in school on day of survey administration.
[b] Seven students did not have NtN Science grades for this year.
[c] Only 6 control students took the NtN Science assessment in this year.
* $p < 0.1$.
** $p < 0.05$.

Table 5
Comparison of Descriptive (unadjusted) and Regression-Adjusted[a] NtN Impacts – Cohort 2.

Outcome Measure	Post 1 (2012–13) Difference (NtN – Cont.)		Post 2 (2013–14) Difference (NtN – Cont.)		Post 3 (2014–15) Difference (NtN – Cont.)		Post 4 (2015–16) Difference (NtN – Cont.)	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Average grade in:								
Math	+4.3[**]	+4.5[**]	+4.6[**]	+4.3[**]	+5.6[**]	+5.3[**]	+6.1[*]	+5.2[*]
Language Arts	+2.3	+2.4	+1.1	+0.5	+1.4	+1.1	+2.6	+2.1
Science	+2.8[**]	+2.9[**]	+1.9	+1.4	−1.6[2]	−1.0	+7.5[**]	+5.5[**]
Science Knowledge	+11.3[**]	+8.3[**]	+15.4[**]	+14.7[**]	+16.7[**]	+15.6[**]	+5.4[3]	+5.0
Absences	−1.8[**]	−1.7[**]	−1.0	−1.2	−0.3	−0.1	+0.7	+1.3
Tardiness	−0.1	−0.1	+1.6	+1.5	+1.1	+1.1	−2.1	−2.0

[a] Regression results adjust for gender, race/ethnicity and language spoken at home.
[2] Seven students did not have NtN Science grades for this year.
[3] Only 6 control students took the NtN Science assessment in this year.
* $p < 0.1$.
** $p < 0.05$.

differences in science knowledge ranging from 10.4 to 20.2 points are significant in each of the three post program years. NtN students had significantly fewer days of absence and tardiness generally, but significantly so only in Post Year 1. Again the comparisons shown in Table 7 indicate the equivalence of unadjusted and adjusted impact estimates.

Tables 8 and 9 show 2-year NtN impacts for Cohort 5, which show substantial program impacts on NtN students' grades in mathematics, language arts, and science. NtN students significantly outperformed their control counterparts in mathematics by about 5 points in each of the two years. They also demonstrated significantly higher grades in science 4.2 points in Post Year 1 and 5.3 points in Post Year 2. Increases in language arts grades also occurred in both years, however only the Post Year 1 difference of 4.2 points is statistically significant. The NtN group also exhibited significant and impressive differences in science knowledge over the control group, scoring between 10.2 to 22.4 points higher in the assessment across the two years. While we observe no differences with respect average absence days, NtN students did have significantly fewer tardy days in both years. Table 9 validates the unadjusted results, and if anything, tends to indicate that the adjusted

Table 6
Cohort 4 – Three Year NtN Impacts – Descriptive Results.

Outcome	Post 1 (2013–14)		Post 2 (2014–15)		Post 3 (2015–16)	
	NtN	Control	NtN	Control	NtN	Control
Average grade in:						
Math	81.5*	77.9	82.5	79.7	78.7	77.4
Language Arts	78.4	76.3	80.8	79.8	75.9	77.0
Science	88.6**	83.8	88.2	87.3	81.2	81.8
Science Knowledge Assessment (% Correct Response)	56.6**	46.3	59.2**	39.0	51.1	33.3
School Absences (Days)	3.5**	4.9	3.5	4.6	4.6	5.1
Tardiness (Days)	1.4*	2.1	1.5	1.8	2.6	3.3
[a]n	15	119	13	110	19	101

[a] Number of observations may vary for academic vs. survey data - number of observations from survey data depends on student presence in school on day of survey administration.
* $p < 0.1$.
** $p < 0.05$.

Table 7
Comparison of Descriptive (unadjusted) and Regression-Adjusted[a] NtN Impacts – Cohort 4.

Outcome Measure	Post 1 (2013–14) Difference (NtN – Cont.)		Post 2 (2014–15) Difference (NtN – Cont.)		Post 3 (2015–16) Difference (NtN – Cont.)	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Average grade in:						
Math	+3.6*	+3.0	+2.8**	+2.8	+1.3	+1.3
Language Arts	+2.1	+1.7	+1.0	+1.3	−1.1	−0.2
Science	+4.8**	+4.4**	+0.8	+1.1	−0.6	−0.1
Science Knowledge	+10.4**	+10.4**	+20.2**	+19.9**	+17.9**	+18.0**
Absences	−1.3**	−1.0	−1.1	−0.9	−0.5	−0.6
Tardiness	−0.7*	−0.4	−0.3	+0.1	−0.7	−0.5

[a] Regression results adjust for gender, race/ethnicity and language spoken at home.
* $p < 0.1$.
** $p < 0.05$.

Table 8
Two Year NtN Impacts for Cohort 5 – Descriptive Results.

Outcome	Post 1 (2014–15)		Post 2 (2015–16)	
	NtN	Control	NtN	Control
Average grade in:				
Math	80.0**	74.7	81.6**	76.3
Language Arts	79.6**	75.5	75.9	73.9
Science	82.9**	77.6	83.5*	79.3
Science Knowledge Assessment (% Correct Response)	56.5	46.3	58.7**	36.3
School Absences (Days)	6.3	5.9	6.3	6.8
Tardiness (Days)	0.7**	2.9	2.2**	5.1
[a]n	14	69	17	67

[a] Number of observations may vary for academic vs. survey data - number of observations from survey data depends on student presence in school on day of survey administration.
* $p < 0.1$.
** $p < 0.05$.

Table 9
Comparison of Descriptive (unadjusted) and Regression-Adjusted[a] NtN Impacts – Cohort 5.

Outcome Measure	Post 1 (2014–15) Difference (NtN – Cont.)		Post 2 (2015–16) Difference (NtN – Cont.)	
	Unadj.	Adj.	Unadj.	Adj.
Average grade in:				
Math	+5.3**	+6.2**	+5.3**	+5.8**
Language Arts	+4.2**	+5.0**	+2.0	+2.5
Science	+5.3**	+6.1**	+4.2	+5.1**
Science Knowledge	+10.2**	+10.2**	+22.4**	+23.0**
Absences	+0.4	−0.03	−0.5	−0.7
Tardiness	−2.2**	−2.0	−2.8**	−2.6

[a] Regression results adjust for gender, race/ethnicity and language spoken at home.
** $p < 0.05$.

impacts are slightly higher.

Tables 10 and 11 combine the results for the remaining two cohorts − Cohorts 6 and 7–for two years. Overall, for both of these cohorts in both the years, the results indicate no statistically significantly differences between the NtN and control groups in any of the outcome measures except science knowledge. Many of the differences are not in the expected direction, with NtN students performing at a lower level in math, language arts and science and having more absences or tardiness, although none of these differences reach statistical significance. The pattern of results in these two cohorts is especially puzzling inasmuch as Cohort 6 students comprise students from the poorest SES tracts in the city while Cohort 7 includes students from the wealthiest tracts. Table 11 results do not completely agree with Table 10's unadjusted results with respect to statistical significance, showing a significantly lower math grade and higher NtN group tardiness for Cohort 6 in Post Year 2; and a significantly lower science grade for Cohort 7 in Post Year 2. However, with respect to the science knowledge assessment the NtN students score significantly much higher relative to controls in both years, with the difference ranging from 11.9 to 13.3 points for Cohort 6 and 8.5 to 12.4 points for Cohort 7.

Table 12 shows NtN impact on students' interest in STEM related subjects. For the control group students, regular school curriculum was used as the reference, while NtN students were asked specifically if NtN had stimulated their interest in these areas. Cohorts 1, 4, 5, 6, and 7 all reported a higher level of interest in science than their control peers, with three of these groups (Cohorts 1, 4, and 5) also showing statistically significant and increased interest in nature and the environment. Only one of the seven cohorts (Cohort 2) reported an increased interest in mathematics, while in none of the cohorts was there a significant difference with respect to use of technology.

5.1. Summary of impacts

We summarize our key findings on NtN program impact as follows:

- Overall congruence between unadjusted and regression-adjusted estimates of NtN impact estimates provides evidence for the integrity of randomization.
- Three of the six cohorts included in our analyses exhibited consistent, positive and significant NtN impacts in their mathematics school grade (Cohorts 2, 4 and 5) ranging from 2.8 to 6.2 points.
- Two of the six cohorts demonstrated consistent, positive, and significant impacts in their language arts school grade (Cohorts 1, and 5) ranging from 3 to 5 points.
- Four of the six cohorts showed positive and significant impacts in school science grades (Cohort 1 for two of six years; Cohort 2 for two of four years; Cohort 4 for one of three years; and Cohort 5 in both years), with impacts ranging from 2.9 to 7.5 points.

Table 10
Two Year NtN Impacts for Cohorts 6 and 7 – Descriptive Results.

Outcome	Cohort 6				Cohort 7			
	Post 1 (2014–15)		Post 2 (2015–16)		Post 1 (2014–15)		Post 2 (2015–16)	
	NtN	Control	NtN	Control	NtN	Control	NtN	Control
Average grade in:								
Math	75.0	76.6	74.2	77.2	82.9	80.9	77.7	77.9
Language Arts	76.4	77.1	81.2	80.0	80.7	81.8	78.5	80.1
Science	78.4	80.3	80.9	82.0	83.4	83.8	88.5	88.6
Science Knowledge Assessment (% Correct Response)	54.5**	41.2	60.8**	48.9	62.5**	54.0	61.3**	49.0
School Absences (Days)	8.0	7.9	9.0	7.9	5.3	5.9	6.2	5.4
Tardiness (Days)	7.7	9.5	13.4	7.9	3.7	3.2	2.5	4.6
[a]n	18	34	17	28	17	16	17	15

[a] Number of observations may vary for academic vs. survey data - number of observations from survey data depends on student presence in school on day of survey administration.
** $p < 0.05$.

Table 11
Comparison of Descriptive (unadjusted) and Regression-Adjusted[a] NtN Impacts – Cohorts 6 and 7.

Outcome	Cohort 6				Cohort 7			
	Post 1 (2014–15) Difference (NtN – Cont.)		Post 2 (2015–16) Difference (NtN – Cont.)		Post 1 (2014–15) Difference (NtN – Cont.)		Post 2 (2015–16) Difference (NtN – Cont.)	
	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.	Unadj.	Adj.
Average grade in:								
Math	−1.6	−0.1	−3.0	+4.6*	+2.0	−1.3	+1.8	−2.4
Language Arts	−0.7	−0.2	+1.2	−0.2	−1.1	−2.8	−1.6	−4.1
Science	−1.9	−1.2	−1.1	−2.0	−0.5	−1.8	−0.1	−3.1*
Science Knowledge	+13.3**	+14.6**	+11.9**	+12.0**	+8.5**	+7.5	+12.3**	+12.4**
Absences	+0.1	−0.5	+1.1	+1.8	−0.6	−1.3	+0.8	+0.4
Tardiness	−1.8	−2.4	+5.6	+7.3**	+0.5	+0.2	−2.1	+0.1

[a] Regression results adjust for gender, race/ethnicity and language spoken at home.
* $p < 0.1$.
** $p < 0.05$.

- All six cohorts showed substantial, positive, and significant gains over their peers in the control group in their science knowledge. For five of these six groups, the knowledge gain was statistically significant in each of the post program years. The impact estimates on this outcome ranged from 8.3 to 23 points.
- Compared to control peers change, five of the six cohorts (Cohorts 1, 4, 5, 6, 7) reported significantly higher interest in science from participating in NtN; one of the cohorts (Cohort 7) had its interest raised in mathematics; and three of the six cohorts (Cohorts 1, 4, and 5) showed higher interest in nature and the environment.

6. Discussion and concluding remarks

The Nurture thru Nature program is designed as an active learning, educational strategy to (1) help close the achievement gap between poor, minority students and more privileged students; (2) stimulate student interest in STEM careers; and in so doing, (3) improve human capital outcomes of inner-city minority youth. From the preceding summary of impacts, it is clear that the program did not have a uniformly positive impact in all the cohorts. One possible reason for this uneven impact could be a school effect or a grade effect or a grade-school interaction effect. Another possibility is the level of enthusiasm that either NtN students or NtN teachers bring to the program, and their possible interaction with the school effects. As data accumulates from this experiment we continue to examine the plausibility of these possible explanations for uneven program impact and remain vigilant should other explanations reveal themselves.

This focus on improving grades serves a dual purpose in what are

Table 12
NtN Impacts on interest in STEM Subjects – 2015–26 – All Cohorts.

Subject	Cohort1		Cohort2		Cohort4		Cohort5		Cohort6		Cohort7	
	NtN	Cont.	NtN	Cont.	NtN	Cont.	NtN	Cont.	NtN	Cont.	NtN	Cont.
[a]Tell us if your school (or NtN for NtN students) increased your interest in:												
Science	8.0*	5.2	8.4	8.3	8.9*	7.0	8.9*	7.1	8.9*	6.5	8.3*	6.8
Mathematics	7.2	5.5	7.4	6.3	7.8	7.2	6.6	5.9	5.9	6.6	6.7*	4.7
Using technology (e.g., designing and using Power Point presentations, using other computer software)	8.5	7.9	7.8	8.3	9.3	7.8	8.9	7.7	7.8	8.6	7.6	7.8
Nature and the environment	8.3*	5.1	8.0	8.0	9.4*	6.6	8.9*	7.7	8.6	7.7	8.6	7.1

[a] Measured on a scale of 0–10, with 0 = Not at all and 10 = Very much.
* $p < 0.1$.

becoming increasingly resource-depleted urban public schools. While introducing students to natural and environmental science, NtN program also provides beleaguered school administrators and teachers with a clear rational for supporting this initiative with scarce school resources, e.g., classroom space, transportation for field trips, expanded science/environmental clubs, etc. Improved grades, fortunately or unfortunately, are the currency used to obtain broader stakeholder support at the national, state and local levels in many disadvantaged school districts.

NtN marks an attempt to institute what John Dewey (1976: p.92) had termed the University Elementary School, starting with elementary school children's personal interests in nature and introducing deeper learning sequences, specialized topics, and abstract concepts (including mathematics) from year to year. NtN shares its Deweyan parentage with several other models of sustainability education, especially the Head-Heart-Hands approach discussed by Orr (1992) and Singleton (2015). As noted earlier, however, NtN extends the place-based focus of the paradigm to account for the resource depleted realities facing many of our inner-city schools.

NtN approaches this reality with a hegemonic HEAD, Heart and Hands focus that increases an appreciation for nature's aesthetics and utilizes hands-on involvement with science and nature without losing sight of the critical role that academic achievement plays in the lives of students and those charged with their education.

If a HEAD, Heart and Hands philosophy is to flourish, we concur with Sund and Lysgaard (2013) when they assert

> "education should be situated in the actual moment and solve the complex issues contained within a school project and not focus on a specific long-term goal or develop tools that may be applicable in future situations" (p.1606)

Students struggling with substantial mathematics and language arts deficits do not typically have the luxury of engaging in political discussions around "how best to save the planet" or "best practices for sustainability" no more than do failing public schools typically have the capacity to compete as Green Ribbon Schools. This is not to say that such discussions are unimportant, only that they are likely to be more substantive when students have acquired a basic set of science, mathematics and language arts skills and knowledge.

6.1. Lessons learned

Some lessons learned during the design and implementation of NtN are as follows

- Implementation of a science based enrichment program in disadvantaged urban schools requires the buy-in of school administration.
- To gain this buy-in, the program must offer tangible rewards not only to students but also to school administration whether in the form of improved grades, test scores, or some other form of measurable achievement.
- Parental involvement, trust, and cooperation are indispensable to insure high levels of student participation, which cannot be guaranteed by school administration.
- Transfer of the NtN model to districts without the resources of a major corporate and college/university presence remains questionable.

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